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The Influence of the Problem-Based Learning Model Integrated with SDGs-7 on Critical Thinking and Collaboration Skills

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Abstract: The demands of 21st-century education require students to develop critical thinking and collaboration skills to solve real-world problems and work effectively in teams. This study aims to examine differences in students' critical thinking and collaboration skills between classes taught using a Problem-Based Learning (PBL) model integrated with the Sustainable Development Goals (SDGs) and those taught using the discovery learning model. It also investigates the simultaneous effect of the PBL–SDGs model on both skills. This study employed a quasi-experimental method with a nonequivalent control group design involving 38 eighth-grade students at a junior high school. The learning implementation focused on energy topics related to SDG 7 (affordable and clean energy). Data were collected using a validated critical thinking test and a collaboration questionnaire and analyzed using normalized gain (N-Gain), independent sample t-tests, and MANOVA. The results showed that the experimental class achieved higher improvements in critical thinking (N-Gain = 0.55) and collaboration (N-Gain = 0.43) than the control class (0.20 and 0.16). The t-test results indicated significant differences in critical thinking ($p = 0.000$) and collaboration ($p = 0.001$), while MANOVA confirmed a significant simultaneous effect ($p < 0.05$). These findings suggest that SDGs-integrated PBL can effectively support the development of critical thinking and collaboration skills and provide practical guidance for teachers in implementing contextual science learning.

Keywords: Collaboration skills; Critical thinking; Energy learning; Problem-based learning; SDG 7.

Introduction

Education serves as the fundamental foundation for a nation's development. Quality education equips younger generations with the knowledge and skills necessary to address future challenges (Susianita & Riani, 2024). The 21st century is characterized by increasing technological sophistication, practicality, and speed, primarily driven by the advancement of information and communication technology (ICT). These global shifts require high-quality human resources across all sectors, including education (Husain & Kaharu, 2020; Mardhiyah et al., 2021). To meet these demands, education must not only transfer knowledge but also develop essential life skills.

In this context, educators are expected to prepare students with competencies that support success in the 21st century. According to the American Association of Colleges for Teacher Education and the Partnership for 21st Century Skills, critical thinking, creativity, collaboration, and communication are key skills that must be mastered by students (Nurhayati et al., 2024). Therefore, instructional models must be designed not only to convey subject content but also to strengthen students' thinking and social competencies.

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Critical thinking plays a crucial role in enabling students to solve everyday problems effectively and make rational decisions (Ariadila et al., 2023; Purba et al., 2024). However, empirical evidence indicates that students' critical thinking skills remain relatively low. Several studies report that students often experience difficulties in analyzing problems, evaluating information, and drawing logical conclusions (Atris Yuliarti Mulyani, 2022). These limitations are frequently associated with learning practices that still emphasize memorization rather than higher-order thinking skills.

Likewise, collaboration is an essential skill for learning and social interaction. It fosters the exchange of knowledge, joint problem solving, and group productivity (Wulandari et al., 2021). Nevertheless, collaboration skills among students are still underdeveloped. This condition is often caused by teacher-centered learning models that provide limited opportunities for students to actively interact and work together in solving problems (Indahsari & Habiddin, 2024; Mustofa, 2021). As a result, students tend to rely on individual work rather than collective problem-solving processes.

Based on preliminary observations conducted in the research school, learning activities were still dominated by teacher explanations, while opportunities for students to discuss, analyze problems, and collaborate in groups were relatively limited. This situation potentially affects the development of students' critical thinking and collaboration skills. Therefore, learning strategies that actively involve students in problem-solving and teamwork are needed to address these challenges.

To overcome these limitations, appropriate learning models must be implemented. One promising approach is the Problem-Based Learning (PBL) model, which emphasizes student-centered learning, authentic problem solving, and collaborative group work (Effendi et al., 2021; Pamungkas & Wantoro, 2024). Through PBL, students are encouraged to explore real-world problems, thereby enhancing both cognitive and social-emotional skills (Ramadhani et al., 2024).

In the context of science learning, energy-related issues represent relevant and meaningful content. Fossil energy such as petroleum, coal, and natural gas still dominates Indonesia's national energy supply, while renewable sources remain underutilized (Pahrudin et al., 2022; Sarante, 2024). This overreliance contributes to increased greenhouse gas emissions, which trigger climate change and ecosystem imbalance (Rachman et al., 2020). These problems are closely aligned with Goal 7 of the Sustainable Development Goals (SDGs), which promotes access to affordable and clean energy.

Integrating the SDGs into science learning through PBL is considered an effective approach to contextualize learning and increase students' awareness of global sustainability issues (Yonanda et al., 2023). Through real-world energy problems, students are encouraged not only to understand scientific concepts but also to develop sustainable solutions and responsible attitudes toward environmental challenges.

Previous studies have shown that the PBL model positively affects either critical thinking skills or collaboration skills (Astuti et al., 2021; Indahsari & Habiddin, 2024; Pratama & Mardiani, 2022). However, most of these studies focus on a single competency, while limited research examines the simultaneous effect of integrating PBL with SDGs-based learning on both critical thinking and collaboration skills in science education. This gap indicates the need for further research to explore how SDGs-integrated PBL can support the development of multiple 21st-century competencies simultaneously.

The novelty of this study lies in examining the integrated effect of the PBL model enriched with SDGs on students' critical thinking and collaboration skills simultaneously. It also provides empirical evidence in the context of junior high school science learning using real-world energy issues. The findings of this study are expected to contribute to the development of innovative science learning strategies that support the integration of SDGs and the strengthening of students' 21st-century competencies.

Based on these considerations, this study aims to: (1) analyze the differences in students' critical thinking skills between classes using the PBL model integrated with SDGs and those using the discovery learning model; (2) analyze the differences in collaboration skills; and (3) determine the simultaneous effects of implementing the PBL model integrated with SDGs on students' critical thinking and collaboration skills.

Method

This research was conducted at SMP Muhammadiyah 3 Depok during the 2024/2025 academic year. The study focused on energy topics in science subjects for eighth-grade students. This study employed a quasi-experimental method using a nonequivalent control group design. The population of the study consisted of all eighth-grade students at SMP Muhammadiyah 3 Depok in the 2024/2025 academic year.

The sample included two classes selected using purposive sampling to ensure that the classes had similar instructional characteristics and learning conditions. Class VIII A was designated as the experimental group, while Class VIII B served as the control group. The experimental class was taught using

the Problem-Based Learning (PBL) model integrated with the Sustainable Development Goals (SDGs), while the control class was taught using the discovery learning model.

The independent variable in this study was the PBL model integrated with SDGs, while the dependent variables were students' critical thinking skills and collaboration skills. Data were collected using a multiple-choice test and a questionnaire. The critical thinking test consisted of 25 items developed based on four indicators: explaining, interpreting, analyzing, and evaluating. The collaboration questionnaire used a 1–4 Likert scale and was developed based on collaboration indicators, there are covering aspects such as participation, interaction, empathy, task completion, group adaptability, and concern for others. (Greenstein, 2012; Griffin et al., 2012). All instruments underwent validity and reliability testing prior to implementation. The reliability coefficient of the critical thinking test was 0.85, categorized as very high, while the collaboration questionnaire obtained a reliability coefficient of 0.91, also categorized as very high.

The research was conducted through several stages. First, the preparation stage involved developing research instruments, validating the instruments, and determining the research sample. Second, the implementation stage included administering a pre-test and an initial collaboration questionnaire to both classes to measure students' initial abilities. Afterward, the learning intervention was carried out in two meetings totaling four lesson hours. The experimental class received instruction using the Problem-Based Learning (PBL) model integrated with SDGs, while the control class received instruction using the discovery learning model. Third, after the learning intervention was completed, a post-test and a final collaboration questionnaire were administered to measure students' critical thinking and collaboration skills after the treatment.

Data analysis was conducted using normalized gain (N-Gain) scores, independent sample t-tests, and multivariate analysis of variance (MANOVA) with the assistance of IBM SPSS Statistics 25. The N-Gain score was used to measure the improvement in students' critical thinking skills and was calculated using formula 1:

$$\langle g \rangle = \left(\frac{S_f - S_i}{S_{maks} - S_i}\right) \quad (1)$$

Information:

$< g >$ = Gain score

S_f = Posttest score

S_i = Pretest score

S_{maks} = Maximum score

where <g> represents the gain score, Sf represents the post-test score, Si represents the pre-test score, and Smaks represents the maximum score. N-Gain values above 0.70 are categorized as high, values between 0.30–0.70 are categorized as medium, and values of 0.30 or lower are categorized as low (Hake, 1998).

Prior to hypothesis testing, prerequisite tests were conducted. The Shapiro–Wilk test was used to assess the normality of the data distribution. The results indicated that the pre-test and post-test scores for critical thinking as well as the initial and final collaboration questionnaire scores had significance values greater than 0.05, indicating that the data were normally distributed. Homogeneity of variance was tested using Levene's test, which showed significance values greater than 0.05, indicating homogeneous variances. The homogeneity of the variance–covariance matrix was examined using Box's M test, which yielded a significance value of 0.089, indicating that the covariance matrices were homogeneous across groups. In addition, a Pearson correlation test was conducted to examine the relationship between critical thinking and collaboration variables, which produced a significance value of 0.009, indicating a statistically significant correlation between the two variables. These results confirmed that the assumptions required for conducting the MANOVA test were fulfilled.

Result and Discussion

The effect of PBL–SDGs on students' critical thinking skills

Learning using the Problem-Based Learning (PBL) model integrated with SDGs in the energy topic was conducted in two meetings with a total duration of four lesson hours. The learning process in the experimental class followed the stages of the PBL model integrated with SDGs, while the control class applied the discovery learning model. The first objective of this study was to analyze the difference in students' critical thinking skills between the class taught using the PBL model integrated with SDGs and the class taught using the discovery learning model. The improvement in students' critical thinking skills was analyzed using the N-Gain score, as presented in Table 1.

Table 1. Critical Thinking Ability N-Gain Score Data

Class	Pre-test	Post-test	N-Gain	Category
Experiment	45	76	0,55	Medium
Control	46	58	0,20	Low

Table 1 shows that the experimental class obtained an N-Gain score of 0.55 (medium category), while the control class obtained an N-Gain score of 0.20 (low category). This result indicates that the improvement in students' critical thinking skills in the experimental class was higher than that in the control class. To determine whether the difference was statistically significant, an

independent sample t-test was conducted using IBM SPSS Statistics 25, with the results presented in Table 2.

Table 2. Independent Sample T-test of Critical Thinking

Levene's Test for Equality of Variances		T-test for Equality of Means		
F	Sig	t	df	Sig (2-tailed)
0,189	0.666	7.986	36	0.000

Based on Table 2, the significance value obtained was 0.000 (Sig < 0.05), indicating a significant difference in students' critical thinking skills between the experimental and control classes. This result suggests that the PBL model integrated with SDGs is more effective in improving students' critical thinking skills than the discovery learning model.

These findings are consistent with previous studies. PBL model significantly improves students' critical thinking skills compared to discovery learning (Astuti et al., 2021). Students taught using the PBL model achieved higher critical thinking scores than those taught using the discovery learning model (Pratama & Mardiani, 2022).

The effectiveness of the PBL model in improving critical thinking skills can be explained by the characteristics of the learning model. PBL emphasizes problem-solving activities that require students to analyze problems, evaluate information, and propose solutions. In contrast, discovery learning focuses more on discovering concepts through exploration (Tuti, 2021). Discovery learning emphasizes information searching, while PBL emphasizes solving contextual problems (Asmal, 2023).

In this study, the integration of SDGs—particularly Goal 7 on affordable and clean energy—provided contextual problems related to students' daily lives. These contextual problems encouraged students to think critically about real-world issues, which ultimately contributed to improving their critical thinking skills. The improvement in each critical thinking indicator is presented in Figure 1.

The explanation indicator obtained the highest N-Gain score of 0.73 in the experimental class. Explanation refers to the ability to present arguments based on evidence and logical reasoning (Facione, 2011). The high score on this indicator may be attributed to learning activities that required students to explain energy concepts, describe phenomena, and communicate ideas during discussions. Students involved in active group discussions tend to achieve higher scores on the explanation indicator because they frequently practice articulating ideas clearly (Aggraini et al., 2024). Similarly, the PBL model can enhance students' problem-solving abilities, including improvements in the explanation indicator (Sukmawarti et al., 2022).

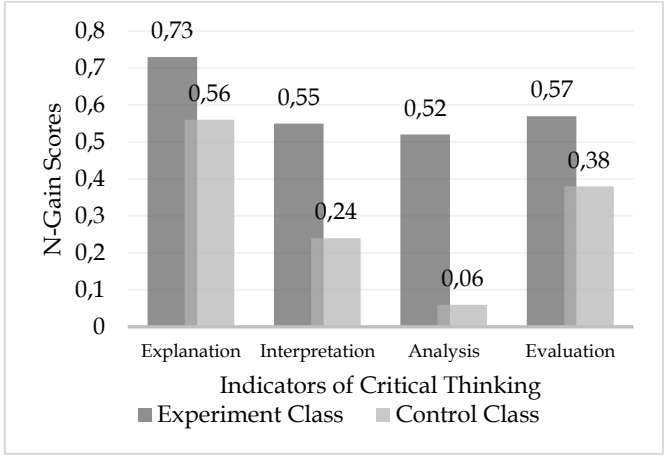

Figure 1. The improvement in each critical thinking indicator

The interpretation indicator obtained an N-Gain score of 0.55 (medium category). Interpretation involves understanding and expressing the meaning of information, events, or data (Facione, 2011). The improvement in this indicator indicates that students were able to interpret problems related to energy issues presented during the learning process. Interpretation refers to students' ability to understand and convey the essential meaning of a problem, which in this study was measured through questions requiring students to explain the meaning of the given problem (Solikhin et al., 2024). The PBL model can improve students' critical thinking skills, particularly in the interpretation indicator (Sihaloho & Saragih, 2024).

The analysis indicator obtained the lowest N-Gain score of 0.52. Analytical thinking requires students to identify relationships between statements, arguments, and concepts, and this skill often develops gradually because it involves complex reasoning processes (Facione, 2011). Lower scores in the analysis indicator are often caused by students' limited experience with analytical tasks. Nevertheless, the analysis indicator in this study still showed improvement, although not as high as other indicators, likely due to the contextual energy problems presented during learning activities that stimulated students' critical thinking (Fauziana et al., 2021). The implementation of the PBL model can improve critical thinking skills by presenting real-life problems relevant to students' daily lives (Narsan, 2024).

The evaluation indicator obtained an N-Gain score of 0.57. Evaluation involves assessing the credibility of statements and the strength of arguments (Facione, 2011). The improvement in this indicator may be influenced by the stages of the PBL model that require students to analyze problems, seek evidence-based solutions, and evaluate the proposed solutions during

problem-solving activities. The PBL model can enhance students' evaluation skills (Sari et al., 2022).

The effect of PBL–SDGs on students' collaboration skills

The improvement in students' collaboration skills was also analyzed using N-Gain scores, as presented in Table 3.

Table 3. Collaboration Ability N-Gain Score Data

Class	Pre-test	Post-test	N-Gain	Category
Experiment	58	77	0.43	Medium
Control	60	67	0.16	Low

Table 3 shows that the experimental class obtained an N-Gain score of 0.43 (medium category), while the control class obtained an N-Gain score of 0.16 (low category). This result indicates that the PBL model integrated with SDGs provides a greater improvement in students' collaboration skills compared to the discovery learning model. The independent sample t-test results are presented in Table 4.

Table 4. Independent Sample T-test of Collaboration

Levene's Test for Equality of Variances		T-test for Equality of Means		
F	Sig	t	df	Sig (2-tailed)
3,208	0.082	3.464	36	0.001

Based on Table 4, the significance value obtained was 0.001 (Sig < 0.05), indicating a significant difference in collaboration skills between the experimental and control classes.

This finding supports previous studies indicating that PBL effectively enhances collaboration skills. PBL improves students' collaboration skills because it requires students to work together to solve problems (Indahsari & Habiddin, 2024). Collaborative problem-solving activities in PBL encourage students to communicate, share ideas, and work collectively to achieve common goals (Hartina et al., 2022).

The improvement in collaboration skills in this study can be explained by the characteristics of the PBL model, which emphasizes teamwork, discussion, and joint problem-solving. These activities provide opportunities for students to interact, exchange ideas, and develop cooperation skills. The improvement in collaboration indicators is presented in Figure 2.

Based on Figure 2, the indicator of student activity and active participation obtained an N-Gain score of 0.56, which falls into the medium category. This result indicates that students were actively involved in learning activities during the implementation of the PBL model. Students engaged in problem-based learning tend to demonstrate higher levels of participation and active contribution, particularly in articulating ideas and solving problems (Dhitasarifa et al., 2023). PBL enhances students' collaboration skills through group discussions and encourages them to actively express opinions and participate in problem-solving. This active involvement occurs because PBL positions students as the main actors in the learning process, encouraging them to participate directly in identifying and solving problems (Afelia et al., 2023).

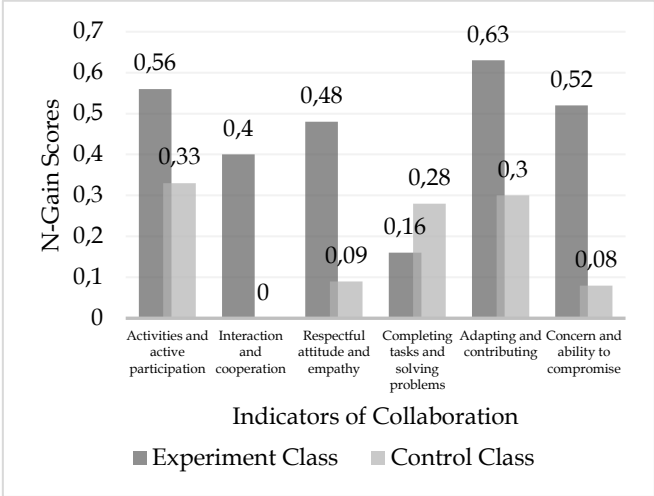

Figure 2. The improvement in each collaboration skills indicator

The student interaction and cooperation indicator obtained an N-Gain score of 0.40, which falls into the medium category. This improvement indicates that students were able to interact and collaborate with their group members during the learning process. Such interaction plays an important role in developing effective cooperation among students. Positive social interaction among students is essential for building effective collaboration patterns, as it enables students to support each other and complete group tasks more efficiently (Aris et al., 2024).

The indicator of respect and empathy obtained an N-Gain score of 0.48, which falls into the medium category. This result indicates that students were able to respect differing opinions and demonstrate mutual respect during group discussions. Students engaged in collaborative problem-solving activities tend to show respect for group decisions and opinions (Dhitasarifa et al., 2023). Students participating in group discussions are able to appreciate their peers' opinions, which contributes to stronger collaboration within the group (Rahmawati et al., 2019).

The indicator of completing tasks and solving problems obtained an N-Gain score of 0.16, which falls into the low category. One possible factor influencing this result is the ineffective distribution of tasks among group members. Effective task distribution can

strengthen students' sense of responsibility and support timely task completion (Nasution et al., 2024). However, some students still demonstrate unequal responsibility when completing group tasks, which may hinder group decision-making. Therefore, clearer task division and stronger individual accountability are needed to support more effective collaboration within groups (Indahsari & Habiddin, 2024). Successful collaboration requires synergy among group members to achieve shared goals (Fitriyah, 2023).

The adaptation and contribution indicators obtained an N-Gain score of 0.63, which is the highest among the collaboration indicators and falls into the medium category. This result indicates that students were able to actively contribute and adapt within their groups during the learning process. PBL encourages students to engage in solving real-world problems by identifying issues, gathering information, evaluating situations, and collaborating to develop solutions (Habsy et al., 2024). Students involved in problem-based learning tend to show active contributions during group problem-solving activities (Dhitasarifa et al., 2023). A significant improvement in students' active participation and contribution, indicating that students begin to recognize the importance of teamwork in achieving group objectives (Nafisah et al., 2024).

The indicators of concern and compromise obtained an N-Gain score of 0.52, which falls into the medium category. This improvement indicates that students were able to understand the needs of their group members and maintain effective cooperation during group activities. Students who are able to adapt to their peers, contribute ideas, and reach compromises tend to demonstrate stronger collaboration skills. The ability to show concern and make compromises is therefore essential in supporting the successful achievement of shared goals within group learning activities (Pratiwi et al., 2020).

Simultaneous effect of PBL–SDGs on ritical thinking and collaboration

To examine the simultaneous effect of the PBL model integrated with SDGs on both critical thinking and collaboration skills, a MANOVA test was conducted. The results are presented in Table 5.

The results show that the significance values for Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root are all 0.000 (Sig < 0.05). This indicates that the PBL model integrated with SDGs has a significant simultaneous effect on students' critical thinking and collaboration skills.

This finding suggests that integrating SDGs issues with the PBL model can support the development of essential 21st-century skills. The integration of SDG Goal 7 on affordable and clean energy provides contextual problems that are relevant to students' daily lives. As a result, students are encouraged to analyze problems critically while working collaboratively to find solutions.

Table 5. MANOVA Test

Effect		Value	Hypothesis df	Sig.
Intercept	Pillai's Trace	0.905	2.000	0.000
	Wilks' Lambda	0.095	2.000	0.000
	Hotelling's Trace	9.567	2.000	0.000
	Roy's Largest Root	9.567	2.000	0.000
Class	Pillai's Trace	0.672	2.000	0.000
	Wilks' Lambda	0.328	2.000	0.000
	Hotelling's Trace	2.047	2.000	0.000
	Roy's Largest Root	2.047	2.000	0.000

Previous studies also support this finding. The PBL model has been reported to enhance students' critical thinking skills (Setiawan, 2022). In addition, PBL has been shown to improve students' collaboration skills (Hartina et al., 2022). Furthermore, the PBL model can simultaneously enhance both critical thinking and collaboration skills (Muliana et al., 2024). Presenting real-world problems in PBL stimulates students' curiosity and encourages them to develop critical thinking and collaboration skills during problem-solving activities (Narsan, 2024).

Based on this discussion, the PBL model not only focuses on enhancing critical thinking skills but also strengthens collaboration skills through the learning process. This indicates that PBL is a comprehensive learning model for developing 21st-century skills, such as critical thinking and collaboration, which are highly relevant in the context of SDGs-based learning, particularly in addressing clean and affordable energy challenges.

Conclusion

Based on the results of this study, it can be concluded that the implementation of the Problem-Based Learning (PBL) model integrated with Sustainable Development Goals (SDGs) effectively improves students' critical thinking and collaboration skills in science learning on energy topics. The results showed that students in the experimental class experienced higher improvements compared to those in the discovery learning class. The N-Gain results indicated a higher increase in critical thinking skills in the experimental class, particularly in the explanation indicator (0.73), followed by interpretation (0.55), analysis (0.52), and evaluation (0.57). Similarly, collaboration skills in the experimental class improved

in several indicators, including adaptation and contribution in groups (0.63), student activity and participation (0.56), concern and compromise (0.52), respect and empathy (0.48), and interaction and cooperation (0.40), although the task completion indicator showed a relatively low improvement (0.16). Statistical testing also confirmed that the PBL-SDGs model had a significant effect on both critical thinking and collaboration skills compared to the discovery learning model.

These findings indicate that integrating real-world issues related to SDG 7 on clean and affordable energy within the PBL model can encourage students to think critically, collaborate actively, and participate in problem-solving activities. Therefore, the PBL-SDGs model can serve as an effective alternative learning strategy for science teachers to develop students' 21st-century skills in the classroom.

However, this study has several limitations. The research was conducted on a limited sample of eighth-grade students and focused only on energy topics, which may limit the generalization of the findings. Future research is recommended to apply the PBL-SDGs model to different science topics, educational levels, and larger sample sizes to obtain broader empirical evidence regarding its effectiveness in improving students' critical thinking and collaboration skills.

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Author Contributions

Conceptualization, D.R.; methodology, D.R.; software, D.R.; validation, R.A.T. and P.A.; formal analysis, D.R.; investigation, D.R.; resources, P.W.H.; data curation, D.R.; writing—original draft preparation, D.R.; writing—review and editing, P.W.H. and E.R.; visualization, D.R.; supervision, P.W.H.; project administration, P.W.H. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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